Unmanned Aerial Vehicle for Pipeline Surveillance: A review

Abstract

Petroleum products being transported through pipelines can be easilytargeted by economic and political saboteurs. Unmanned Aerial Vehicle (UAV) heralds a new technology on pipeline safety, surveillance, surveying mapping, assessment and safety for the oil and gas industry. With the advent of this technology, leaks, corrosion, third party interference and other faults leading to the loss of life, environmental pollution can be checked. This review highlights the state of the technology and benefits of UAV to the Nigeria oil and gas industry. The Nigeria oil and gas industry vested with over 2,300,000 barrels of crude oil daily production has over 9000km pipeline route which is prone to rupture from leaks, corrosion andvandalism. The industry will benefit from a flexible compatible and adaptable UAV platform with a multispectral and hyper spectral sensor for extensive safety, real-time imagery within a localized small to medium spatial scale, over larger expanse ofspace and time. The technology is adjured cheaperfor inspection mission over traditional methods. Adoption of these technology would improve the environmental imprints of the oil and gas companies operating in the Niger Delta, and cases of pipeline vandalism and unrest might be lessened.

Keywords: Oil and gas, pipeline,surveillance,Unmanned Aerial Vehicle

1.0 Introduction

Nigeria foreign exchange depends solely on oil and gas, as over 90% earnings come into the foreign exchange a result. The Niger Delta area is the main seat of this production in Nigeria. The budging of oil and gas pipelines in Nigeria fragments rich ecosystems such as rain forest, arid region, mangroves, savannah, Sahel savannah, dessert which causes a reduction to habitat area, biodiversity and much more [1-4]. Pipelines carry liquids, gases and other allied chemicals via transport over long distances and duration aided by pumps, valves, and control devices. Pipeline leakages, pipe rupture, accidental discharges from tanks, refineries, depots and flow stations, cause ecological imbalance with resultant effects on the health of the people, decline in food production, and eventual death [2,5-7].

Old and exposed oil and gas pipelines are prone to corrosion and failure wit high environmental concern. As pipeline infrastructure gets older there is the need for more frequent visitation to prevent accidents and incidents that could affectthe environment and humans.Theft of crude oil from deliberate sabotage of pipelines, is the major cause of pipeline rupture in the Niger Delta [2,7]. Equipment failure the likes of wear and tear, leaks can occur due to over-age of structures third party (intentional act by vandals, sabotage, theft, etc.) interference, material failure, earth ground movement, incidental, accidental hot-tap or accidental discharge pipe failure can result to large amount of oil and gas loses.Oil and gas spillage deplete vegetations calling for an effective environmental protection and pipeline maintenance culture. The need for all stakeholdersincluding all the oil companies and Federal Government of Nigeria to regardless of size, location or placement of pipelines develop a model to monitor and safeguard the security and safety of all pipelines has been re-echoed at several fora.This they can be done by the effective use a system that ensure monitoring the condition of pipelines to makeprovision for mitigating failures, corrosion, leaks, thefts, sabotage, detecting problems along pipeline right of way of overtime and proffering solution for timely intervention.

To guarantee the safety of petroleum products in Nigeria, security patrol team and safety, equipment are often employed. It is widely known that Unmanned Aerial Vehicles (UAVs), Geographic Information System (GIS) and remote sensing (RS) have been used for military and civil defence, for surveillance purpose [8].They can be useful for georeferencing on the pipeline right of way; network aerial photo and pipeline management. Captured imagery by UAVsprovide datafor GIS uses. These technologies can be applied in oil spill management, used for emergency response, check vandalism and for overall safety of the oil and gas infrastructure. The use of these technologies enables the proponents to operate and maintain pipeline network in a manner that it would continuously ensure and provide un-interrupted product services to customers and end users without any delay, accidents, incident which can adversely affect the reputation of the proponents' company and the ecological environment. These technologies are very cost effective, safety efficacy, accuracy a sit manoeuvres the traditional surveillance where security guides secure the pipeline on continuous patrol on foot and vehicle [9-13,37-39]

Between the first output of oil and now, several million barrels of crude oil have been spilled into the estuaries, land, coastal swamp, waters of Nigeria [[14,15]. The implementation of UAV for pipeline safety in Nigeria is needed because the traditional method even with the inclusion of armed military personnel, has not stopped pipeline breaks by vandals. The cost of restoring the environment following spill is enormous. In 2011, UNEP [16] reported that decontaminating Ogoni land which comprise of four local governments will cost the Federal Government of Nigeria and shell an estimated 880million Euros or 1billion Dollar, aside the financial loses to the stakeholders.

Safety, mapping georeferencing, geospatial analysis of oil and gas pipelines ensures safety of lives, properties, financial growth and proponents' reputation, with particular attention to the present state of industrial or state of the art practice and the sustainable future. To this end, the author reviews the main surveillance technologies for oil and gas pipeline safety; gadgets in use, to which UAVs are expected to add to the capacity and cost-effectiveness; overview of a typical UAV solution with brief description of the most desirable elements but not limited to its platform, auxiliary components and sensor. The present state of the use of UAVs for pipeline safety, the weakness and advantages of such technology as well as the regulations are detailed in this review.The potential benefits of UAVs technology in pipeline safety as an alternative surveillance technology in Nigeria was also covered.

2.0 History and Concepts of Unmanned Aerial Vehicle (UAVs)

UAVs vehicle is the technique or method of collecting geometrics (which is the study of the land and sea making use of vehicles, mapping, and GIS to foster highly accurate digital data of the environment. This is later used to make informed decisions about any development of bridges, roads, pipelines, oil rigs etc) and the use ofUAVs to take photos for effective correspondence in photogrammetry which is the science of making measurements from photographs, or other imagery with the use of airplanes, helicopters, octocopters, UAVs, balloons or other aerial devices. This equipment or machines are suitable for the full aerial vehicle or geodetic vehicle of a study area by creating a point cloud of measurement of almost nearly homogenous quality and accuracy. The UAVs vehicle pattern alludes to detailed point clouds (various types of data) being used in line with or thophotos (study site) etc: to obtained information of the study site.

The earliest use of UAVs dated back to 1849 were primarily used for military purposes – the Austrian balloon. As time progresses, in 1915, the British military used aerial imagery to spy the German troops, later in 1916 the first American UAVs was used in world-war two (Markets and Markets, 2014), WWII with a pilotless aircraft. 1930 was marked with the U.S. Navy experimenting with radio-controlled aircraft curtissN2C-2drones in 1937 in the same vein 1941 was marked with the Reginald Deny and the Radioplane the first large scale production, similarly in 1973, Israel developed the Mastiff UAV and IAA Scout both with unpiloted surveillance machine, 1982 Israeli – Syrian UAVs battlefield where Israeli-unpiloted and piloted aircraft was used to destroy Syrians aircrafts and military. 1985, the secretary of the Navy USA directed the expeditious acquisition of UAV systems for operation. The year 1986 witness yet a reconnaissance drone; A joint U.S. and Israeli project RQ2. Twenty-eight years ago, exactly 1990 gave birth to miniature and microUAVs subsequently, the year 2000 witness the predator drone used to hunt for Osama Bin Ladin. The year 2014 brought about drones used for delivery, video, safety etc.[17,18].

2.0 Application of GIS, GPS, RS and Unmanned Aerial Vehicle (UAVs) on Pipeline Safety and Surveillance

GIS can be used to relate geographical data to pipeline safety, vehicle and surveillance on assets, it helps in planning, execution, implementation, product and service project deliverables in a way that benefits its sustainable conservation measurement and project life span which can be short term, let's say one year to five years (1 – 5 yrs.), (6 – 10 yrs.), 11 – 15 years, 16 years and above even to 100 years. The implementation and management of GIS, GPS imbedded in any UAVs aid in firefighting, search and rescue operation, agricultural and fertilizer application sports, safety, surveillance, medical and deliverables, for instance, any third-party action which may include but not limited to theft, bunkering, leaks, sabotage, vandalism, deliberate pipeline break etc. could result to fire having detrimental effect on the ecological balance, destruction to lives and properties, bad image of the company etc. the use and application of GIS, RS, GPS and UAVs has changed the narrative of cost, repairs, lost, etc to a robust economy under surveillance, safety, vehicle, analysis, etc.

In [19] it was reported that civilian use and application of Unmanned Aerial Vehicles (UAVs), is a grave phenomenon across numerous civil application domains, but not limited to real-time safety, search and rescue, security and surveillance of lives and properties, wireless coverage, application to Agriculture precision, remote sensing. The researchers noted that smart UAVs are the next biggest revolution in the use and application of UAVs technology and the provision of new opportunities especially, in civil development and infrastructure in terms of reduced risks and cost management. That UAVs market value surpasses over $45 dollars in their research project work, UAV civil application and their challenges, their work also discussed the current trends and the future potential UAV uses. Additionally, they pointed out the challenges on UAV applications, including the battery charging capacity challenge, collision avoidance and swarming meet challenge, and security - network challenge and how these challenges will Ftodfateaffectthe use and application of UAVs.

The study by Kochetkovea[20], reveals pipeline leakage of transported combustible liquid or gas substances leads to unmanned scenario of explosion and fire resulting to death and destruction of our ecosystem with production loss and company's ill reputation. The researcher alluded to continued pipeline safety as a way to identify leaks, using Unmanned Aerial Vehicle. That the application of the input RGB signal can help in the analysis of spectral resolution to ascertain pipeline damages including pipeline rupture leaks spreading and effecting on the ground, soil and water body – the multi-zone digital image enables the detection of oil spill and soil pollution. These changes in soil morphology enables us to analyse the changes observed in multi-temporal digital images within the visible region. These solutions are cost effective and reliable thereby allowing reduction in labour and time resources when compared with other techniques and methods used in pipeline safety.

Modern technological advancements have increased the integration ofUAVs in both civilian and military usage and its ability to accomplish tasks in safe, quick and cost-efficient media [21]. UAVs are so encompassing in almost all spheres including architecture, engineering, pipeline Construction etc. UAV technology is deployed in building and bridge inspection, progress surveillance and safety, urban planning, agriculture. The researchers were able to classify all AEC related UAV usage and outlining systematic research literature assessment methodology in which peer-reviewed bibliographical database were queried. This study also assessed and identified the major technological components such as: flying styles, types of platforms, sensors onboard to assist in the development of better integration and understanding the technological implementation in the Architecture, Engineering and construction related UAVs. The study suggests that UAVs integration in AEC domain might exhibit equal or might bring about higher outcomes compared to the conventional method of patrol and surveillance in use today.

The study highlights the control system as autonomous and or manned technique, the types of UAV wing-rotary wing UAV deployed predominantly quadcopters mostly and commonly deployed. Available or off the shelf cameras like thermal and video recording cameras frequently mounted on-board UAV, accompanied by LIDAR and laser scanning devices not limited to other sensors the likes of radio frequency identification and Ultrasonic Board System. UAVs has numerous potentials for integration.

In a report by Suzukietal.[22] investigated two methods used to create real-time hazard maps with the use of UAV – collected imageries and sensor data corresponding to positioning and altitude that was transmitted to a ground base control system. The study reveal that the first method creates photomosaic image of optical imagery gotten from video mode; while the second method orthorectifies – removing effects from the image to make it appear as it is on the map and enables the image be used on GIS database. The second method when applied according to the scholar, has more desirable user interface for sharing disaster information and developing recovery plans. This phenomenon was done by matching imagery with map coordinators allowing the robust GIS software techniques being utilized.

GIS tools are invaluable means in studying numerous types of information and the management of resources which has a potential in contributing to national sustainability. GIS with potential to manipulate, model, analyse, store, query and retrieve information for smart application including conservation planning and safety of soil, water and ecological socio-economic and socio-political activities by humans [23] due to the tragedy of the commons

[24]. At present, various techniques and methods are being deployed for pipeline vehicle. Analysis, control safety, inspection of crudest is the widespread of visual inspection by company workers in conjunction with security and the security watch group having almost zero percent on the safety of lives, properties, fauna and flora, environmental damage, bush fires and loss of lives [16]. UAVs provide and ensure the ideal solution to the unwanted problems associated with the product pipeline resources, UAVs negates limitations faced by other security surveillance methods. UAVs for vehicle mapping, 3D and 2D dimensional view, GIS, safety, surveillance etc presents an easier, cheaper, faster and environmentally friendly method of data collection including imageries, photomosaic, land cover, land use changes etc. Drones as a UAV can enter confined space and narrow path, some drones are noiseless or produce minimal noise, equipped with night vision camera, video camera, thermal, lidar, laser sensor and scanning devices on-board UAV allowing the imageries to be detected by the ordinary human eye. UAVs can be deployed to cover very wide area and difficult to reach location that pose threat to the lives of animals, plants, ecosystem and to man and his or her company reputation.

Geographical Information System (GIS) are deployed for data manipulation, storing, retrieval, and visualization. Furthermore, remote sensing, OIP-digital image processing, geospatial technologies and other devices such as google earth and more, GIS provides and ensure the means to store, retrieve, manage, analyse, integrate and visualize spatial data and other information from multiple devices including UAV platforms. Research provides vivid connotation on oil and gas pipeline related to GIS management of large database or datasets, both new and historical data aided by the internet to share, distribute and monitor more importantly information to others. This technology has been used in time past to ascertain the potential of the North West Ethylene pipeline management network system developed by [25]. In Chmaj, andSelvaraj [26], the authors alluded survey applications implementation by the use of cooperative swarms of UAVs operated as distributed processed system. The researcher classification of distributed processing system applications is as listed: (1) general purpose distributed processing applications, (2) the object to be detected, (3) tracking (4) surveillance, (5) collection of data (6) travel path planning (7) navigation (8) collision avoidance (9) Its coordination (10) environmental safety such as, pipeline safety, safety of assets, fauna and flora, safety of changes observed. Though thepaper did not consider the challenges facing UAVs in these specific application areas and the potential of new UAVs technologies and use.

UAV sometimes called unscrewed aerial vehicle universally known as a drone is any aircraft without a human pilot on-board and a type of unmanned vehicle. All UAVs are a component of UAS (Unmanned Aerial Systems). Which is not limited to a UAV, a ground-based controller or a ground pilot, and a system that communicates between the UAV and the ground-based controller. UAV flight can be operated with various degree of autonomy; either remotely controlled by a ground-pilot or by a on-board computer programme.When compared to crewed aircraft, UAVs are primarily used for very expensive missions termed as "dull' dirty and dangerous" – very fitting to pipeline safety in remote and dangerous places UAVs were firsthand military inclined, their use is rapidly increasing commercially scientific, firefighting, agriculture, search and rescue, building infrastructure inspection, geomatics, geodetic policing, pipeline safety and surveillance product delivery drone racing etc [21,27-30].

3.0 Pipeline vandalism in Nigeria

Pipeline ruptures occasioned by vandal / theft / leak / corrosion and earth movement resulting toenvironmental degradation characterises the Nigerian oilfields. From the security department's mode of operation records, physical security surveillance is what is mostly used at night. These are; the Joint Federal Task Force and NPSC and NPMC, special squad of NSCDC, JTF, and community monitoring team on patrol along pipeline right of way. Also, it was observed that vehicles used by these teams is not equipped with communication gadget and smart devices to track any third-party interference.

Table 1 shows what has been observed for a period of ten (1)) consecutive years spanning from 2004-2012. This trend is occasioned with loss of lives, natural habitat, company bad image, loss of farm lands etc. the justification in this project work is simple as advanced countries deploys UAVs for pipeline monitoring with optimal result. No wonder Dubai Oil Company Management and Aramco stated that not a single drop of oil will leak from her pipeline without her notice through the use of UAV aided technology.

Table 1: Historical Background of Pipeline Vandalization in System 2B pipeline route

Year	Location and impact
2004	Imore, Ilado and Arepofire disaster resulting from vandalism of pipeline.
2006	Abule Egba fire disaster as a result of vandals' failed valve inserted on pipeline
2008	Ijegun Fire Disaster resulting from punctured pipeline from road construction by Lagos State Government and HITEC.
2010	Alagbole/Akute Spillage resulting from failed valve inserted on pipeline by vandals
2010-2011	Idimu(Diamond Estate)underground water pollution resulting from seepage of petroleum product from years of vandalism.
2012	Arepo pipeline rupture leading to loss of lives of staff

Table 2 shows pipeline breaks from 2005-2013 due to vandals' activities. In total over 4,000 breaks occurred along the pipeline right of way. Therefore, the need for unmanned aerial vehicle to reduce to the barest minimum mishap occasioned on the resources, is justified.

Table 2: Record of line breaks on system 2B pipeline route

Year	Number of line breaks Mosimi area
2005	209
2006	480
2007	459
2008	530
2009	483
2010	394
2011	467
2012	309
2013	847
TOTAL	**4,168**

Table 3 shows a trend of crude oil loss from 1999 to 2007.An estimated total sum of sixty-six million five hundred and 650 naira (N66,500,650) as a result of line breaks due to vandalism and corrosion in system 2C Kaduna area.

Table 3: Analysis of total loss of crude oil and repairs in system 2C Kaduna area

Year	No. Of line breaks	Qty of crude loss [barrels]	Cost of crude loss in naira ($1=130 naira)	Cost of repairs	Total cost
1999	3	1000	2,600,000	9,800,000	12,400,000
2000	1	400	1,300,000	6,900,000	8,200,000
2001	1	50	149,500	500,000	649,500
2002	2	450	1,170,000	5,700,000	6,870,000
2003	6	1100	4,078,750	2,830,000	7,415,000
2004	7	835	3,968,250	2,350,000	6,488,250
2005	5	1875	10,968,750	11,350,000	22,318,750
2006	1	200	1,560,000	120,000	1,680,000`
2007	4	400	3,120,000	510,000	3,630,000
TOTAL	**30**	**6310**	**26,440,650**	**40,060,000**	**66,500,650**

Pipeline vandalism leads to product loss, loss of revenue,man hour loss-operational down time, cost of litigations, scarcity of products, maintenance cost, increased pipeline repairs, bad company reputation and loss of lives and properties.

4.0 The Need for Pipeline Safety with Unmanned Aerial Vehicle (UAVs) / Drones

International oil giants and pipeline companies around the world are using drones (UAV) for surveying, mapping and safety of their assets to prevent environmental damage, loss of fund, safety effect on the lives of people and properties, companies' reputation. Once the pipelines are operational, Drones (UAVs) are deployed to help with everything from surveying and mapping during the route-planning and execution process through the pipeline-right-of-way (PROW). A report from the Canadian Energy Pipeline Association (2016), spoke with the project manager at Meridian Vehicles, Mrs. Rachel Kolman, a professional in land surveying and digital mapping. Meridian has been driving and using UAVs or call it drones for over six years to date, to enhance a variety of mapping surveying and modelling tasks and services.

Rachel revealed that using drone has enhanced pipeline companies with route selection aided with ArcGIS software, detailed engineering vehicles, infrastructural construction vehicles which serves as the built vehicles anthropogenic activities showing the project at it current state at any given time. This survey highlights the topography of the terrain and the area, the existing utilities, location of the pipeline assets and boundaries, measuring newly identified routes and pipeline installation, staking the construction footprint and its effect. Pipeline companies must prioritize risk, mitigate, avoid, share and accept risk associated with pipeline resources by maintaining, repairing, use of the best technology to advert negative externalities demeaning the value of its pipeline and to protect them efficiently and effectively against damage caused by third parties.

Traditional pipeline safety by soldiers, police, photogrametry and community guards are capital intensive, but with little or, and adverse effect as the security agents have been accused of conniving with the vandals, leading to the destruction of the environment, effecting on fresh water and underground water contamination and pollution depletion of fauna and flora, loss of lives, properties, soil on termination and farm [16]. Pipelines require a lot of data-programme, data collection and data acquisition in order to operate efficiently, smoothly and safely. Pipeline industry owners, operators and companies professionals are incessantly turning to UAVs to enable them meet the challenges on pipeline safety and surveillance. The United States of America has been at the forefront of commercial growth, findings pointed out that drone activity has climbed from and 40 million in 2012 to about $1billion in 2017 [31].It has been forecasted that commercial drones – both institutional and domestic-consumer applications – will amount to over $31 billion and to $46 billion annually on the USA GDP [31].

According to McKinsey and company, UAV industry will hit over $26 billion by 2026 with the oil and gas companies benefiting significantly. Amongst the required desire on the implementation of UAVs as practically conceived is as a result of Nigeria losing over $11 billion of pipeline resources due to vandals, thieves, sabotage etc over a 4-year period spanning from 2007 to 2011. UAVs can fly in a programmed path and or randomly quickly while, covering large and remote expanse, thereby reducing staff man-hours, costs and numbers of personnel on ground. UAVs do not necessarily require space for its operation. In recent time, UAVs particularly drones are deployed for pipeline safety as it provides efficient area coverage, it videos and photographs data accurately to precision, saves time, very cost effective, it has a high-resolution camera / video sensor, it is noise free, it doesn't pollute the environment, some special UAVs can avoid collision etc.

5.0 Alternative Surveillance Technologies use for Pipeline Safety.

Acoustic-based-sensing methods offer a limitless powerful tool in the field of sensing and safety ranging from iron or soft materials characterization, safety the health of structures, acoustic imaging, defect network characterization, etc. The acoustic wave frequency ranges from 20H2 infrasound to ultrasound gigahertz (GHz-band), altogether with a propagating mode, not limited to longitudinal shear waves on material surface waves, material plate modes etc. when this is applied to a pipeline material network at predefined intervals with the aid of a microphone attached to the pipeline it will detect the sound of any third-party such as an excavator or any human effect and it will determine the location. Sensor cables installed on the pipeline path change their electrical property parameters due to reaction of the cable sheath with the oil and gas spill medium and work and act as a leak detection and system location. This sensing technology is applied to the characterization of gaseous, solid and liquid environment. Vapour safety technologies uses porous tubes installed along the pipeline that allow vapour gases to enter. At regular interval the gas inside the container tube moves into a gas analyser allowing leaks and corresponding location to be ascertained.

5.1 Fibre Optic Cable

These cables are standard equipment for the transmission of video, voice signals and other data that are frequently installed along pipelines to enable communication between remote place pipeline and the proponents or company's control station. Though fibre cables can also be used to measure several physical effects starting with higher local resolution along cable path that stretches up to 80km to even 100km. It is on record that in the year 1987 NNPC built the largest optical fibre cable network in the world. Unfortunately, 32 years to date the system didn't produce any remarkable security success as vandals have been vandalizing the assets that witnessed over 5-billion-naira investment.The fibre optic cable was supposed to sense and detect leaks as well as tempering such as effect on the pipeline by man. The sensor cable is the most sensitive micro-phonic cable in the market. Fiber optical pipeline safety system for preventing and detecting leaks in real time, this system uses distributed acoustic sensing (DAS) technology to convert a standard broadcasting/telecommunication fibre optic cable to a fully distributed sensor that is capable of detecting the properties and characteristics of leaks not limited to the changes associated with noise, ground movement, pressure exerted a temperature simultaneously and in real-time. These four parameters when integrated into a single leak detection and safety system will provide improved sensitivity, reliability and dependence required to identify and validate the safety of the pipeline infrastructure to track leaks faster and with confidence.

5.2 Cathodic and Anodic Protection of Pipeline

Research has shown that whenever a metallic conductor let's consider pipeline placed in an electrolytic environment, stray current occurs. This stray current flow through a conductor-pipeline and leaves at a point of the pipe.

A metallic material in contact with an electrolyte either soil or water normally includes anodic sites, prone to oxidation which is corrosion and cathodic sites known for reduction which is represented as protection, cathodic protection is a method deployed to reduce the corrosiveness of a material metal surface by making that whole equipment the cathode of an electrochemical cell. Here the stray current is discharged trough an external anode to enable current flow through the electrolyte. As a result, the cathode is polarized to the potential to the active open circuit anodes.

Anodic protection can only be used on metals and alloys having active – passive characteristics the likes of titanium, nickel-based, steel, ss alloys. It is utilized in a certain closed-circuit environment. Anodic Protection primarily denotes corrosion protection that is realized by maintaining an active – passive metal in the passive region by an externally applied anodic current.

5.3 Integrated Pipeline Safety Technique

A lot of companies make use of Third-party interference (TPI), Distributed Temperature Sensing (DTS), Distributed Acoustic Sensing (DAS) and Distributed Vibration Sensing (DVS) techniques – these are among the newest pipeline safety solution that integrates a fusion of new sensing and hardware, software detection algorithms with video/real-time presentation. These techniques provide multiple derivable benefits, such as; detection of leaks, flow assurance and third-party interference protection and surveillance of minute imagery.

Distributed Temperature and Acoustic Sensing; A system is used to convert a quality optical fibre into an uninterrupted multi-parameter sensor, Distributed Temperature Sensing detects pipeline leakage by analysing the difference in the hotness or coldness around the metal location and its environment. It also detects the anomalies associated with oil, gas or any liquid escaping, or manages active-heating processes such as in a steam or sulphur pipeline Distributed Acoustic and or Distributed Vibration Sensing detects leaks by some basic parameters such as noise and vibrations including temperature changes and negative pressure waves accustomed with leak. Accidental or liberate third-party interference such as digging or the use of excavator can be detected by DTS, DVS, TPI sensing. These devices show the condition along the PROW at a glance, controlled by easy-to-use graphic interference, it seamlessly integrates UAVs or UAS, CCTV, DTS, DVS and other sensors into a platform. Pipeline networks are vehicle and mapped with colour-code to show the measured pipeline temperatures, as well as instantaneous changes in acoustic energy. Hotspot's location are tabulated and their temperature ranges apportioned. Section of the cable route are defined for flexibility types of alarm and levels incorporated.

5.3.1 Features of DAS, DVS, DTS, and TPIS

1. Leak detection and precise location of gases, water flammable and highly inflammable of hydrocarbons, LPG, LNP and multiphase system 2B, 2BX, 2AX etc pipelines.

2. Third-party interference preventing vandalism, leak theft etc on pipeline right of way (PROW) and damage to pipeline infrastructure.

2. Pipeline rupture detection

4. Pipeline initial ignition spot detection

5. Pipeline Hotspot zone

6. Temperature difference safety of pipe wall for heated pipelines.

7. Pig-tracking

8. Leak detection and slug tracking of multiphase / system lines.

5.4 Unmanned Aerial Vehicles (UAVs)

There are various kinds of UAVs, their application also determines the design and purpose of deployment; the United State of America Air force classification of Unmanned Aerial Vehicles is mainly determined by the size of the flight, flight altitude and its duration. Thus, US force classify it as follows:

(1) Micro-Unmanned Aerial Vehicles comprises of small, extremely portable units.

(2) Long endurance Unmanned Aerial Vehicle with low altitude

(3) Long endurance-medium altitude UAVs

(4) Long endurance with High altitude UAVs. This review exhaustively discusses, the micro-UAV that is very small extremely portable units as they do not require a runway that can be easily deployed to any location be it remote areas or not due to the fact that its easily transported, stored, deployed and accessibility and that they are electrically powered via AC/DC or solar powered capable of powering the electrical motors and are designed to vertically take-off and land (VTOL).

5.4.1 Features of UAVs

UAVs are capable of carrying more than 12KG payloads and can be operated during demanding meteorological conditions.Possess robust carbon-frame and cutting-edge flight electronically embedded. UAVs are Unmanned, controlled and command operation authentic aircrafts. It increases security of life, preservation of the environment, safety of proponent property and reputation, automatic function, simplification and it has standards.

5.4.1 UAVs Legislative Framework

UAV regulationdated back to the year 2000s and the 20th century as futuristic endeavours. Literature reviews on UAV applications emphasize UAV legislative framework: entailed the present international regulatory organization and nati9nal body and give compendium introductory risk – based methodologies, international bodies resolve to harmonizes UAV legislation and the current UAV classifications [32,33] alludes TO the effect of regulations for UAV operability in the united states of America and extensive buttress the safety procedures needed. This legislative component in part stressed back to manned aircraft aviation and the emergence of a new era of airplanes during and after World War II. In 1944, the first aviation principle was established by the international community at the Chicago convention which focuses on safety requirements and flight safety of manned air planes aviation and the need for special authorization of the new breed of UAV operations. The United States of America in its article Zacc Dukowitz (20 June 2019). Highlights that; “Not air craft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting state without special authorization by the state and in accordance with the terms of such authorization. Each contracting state undertakes to ensure that flight of such aircraft without a pilot in regions open to civil aircraft shall be controlled as to obliviate danger to civil aircraft" – Extracted from article 8. Jarus being a group of 49 National authorities (12/2016) and experts in the field of UAV. The organization was founded in 2012 as an international body seeks to harmonize standards, provide guidelines and regulations to foster the development and operability of UAV with material support and technicality, they made distinct recommendation on the safety of UAV, operation and that the weight should not exceed 150kg [32]amongst others is the licensing of personnel and operational Area [33] The European union announces new Unmanned Aerial Vehicle-Drone rules, regulations aimed at building common European market use and operations. The application covers both recreational and commercial Unmanned Aerial Vehicle operations. These rules when implemented will override all the existing National rules. According to the European Aviation Safety Agency (EASA) Patrick Ky, noted that common rules will foster investment, innovation, and growth in this promising sector-the EU hope to implement this rule by July [34]. About 18 countries banned the use and flying of drones such as, Cuba, Cote d'ivorie, Brunei; Nicaragua, Moroco, Madagascar, Kyrgystan, Kuwait, Kenya, Iraq, Iran, Babbado, Algeria, [33]. Though some Africa countries lack drone laws whiles some have a robust law such as Rwanda, Namibia and South Africa leaving the way. Nigeria on its part, according to Nigeria's National aviation Authority, the Nigeria Civil Aviation Authority (NCAA), stated that flying a drone is legal in Nigeria, however recommends some stringent regulations. The general rule of flying a drone, the rule are:

(1). It is unlawful to operate a drone without first seeking the required authorizations flight plans must be submitted to the NCAA for authorization prior to conducting each individual drone flight within Nigeria.

(2). Drones weighing more than 250 grams (.55 pounds or 0.25kg) must be registered with remotely piloted Aircraft systems certificate prior to flying in Nigeria.

(4) All drones' operators must be 16 years or age or older.

(5) The operation of drone should not disturb or cause injury to personnel, properties or other aircrafts.

(6) Operators should not fly into a state or across a border.

(7) If an operator must fly across the high sea, then a permit from Air Traffic control is needed though an operator has a permit to fly in his/her custody.

The process of getting a permit or license is very rigorous not limited to a fee of 20 million – for license, 500,000 for registration with NCAA etc.

5.4.2 Major types of Drones Deployed

1. Multi Rotor Drones (UAV)

2. Fixed wing UAV – Drone

3. Single Rotor Helicopter

4. Fixed Wing Hybrid VTOL (Vertical Take-Off and Landing) UAV/Drones can be classified on different basis such as its "usage" - like drone for photography, Drone for

mapping, surveillance etc. The study here shows that the best classification is based on the aerial platforms.

1. Multi-Rotor Drones are the most available common drones used by professionals and hobbyist. They are mostly used for common application for aerial photography, aerial video surveillance etc. amongst these four major UAVs – Drones, multi-rotor Drones are the easiest to manufacture and the cheapest option of UAV – Drone Available. These drones are further classified based on the number of rotors on the platform. Includes tricoptor – 3 ROTORS, Quadcopters 4- rotors, Hexacopter – 6 rotors and Octocoptors – 8 rotors. Quadcopters is the major kind of the multirotor drones in use today because it is very cheap, durable and it hardly cause damage though it uses much of its energy to stabilize thereby not lasting more than 30 minutes, les payload like camera.

2. **Fixed Wing UAV – Drone**: Uses a wing like the normal air planes at the aerodrome, it requires insignificant amount of energy to stay afloat on air, it moves forward on it's set course by the ground control unit. Most fixe wing UAV has an average of 2 hours. When it is powered by a petrol/gas engine it can fly up to sixteen hours and more. Fixed wing drones are ideal for long distance operations – safety, mapping, surveillance but it may not be used for photography because it cannot be placed at a point. It requires a very huge amount of money for the purchase, a runway is needed or a catapult launcher to set it on air. High level of training and expertise is needed.

3. Single rotor UAVs (Drones) are more efficient and stable than multi-rotor drone due to the smaller number of rotors, it can be powered by gas engine, it is very expensive with operational complexity and risks. High level of training is required before flying.

4. Hybrid Vertical Take-Off and Landing (VTOL): This UAV uses and combines the benefits of multi-rotor-based flight hove with that of fixed wing models having higher flying times, though it is still being tested, it has new generation sensors the likes of gyros and accelerometers. It uses automation and manual gliding working on programmed remote based, gyros and accelerometer in automated made-autopilot control.

6.0 Environmental Benefits of using UAVs in Pipeline surveillance

Pipelines are one of the assets of Nigeria, when the coatings and the pipe material become disbanded caused by various chemical, electrochemical, mechanical, environmental factors (such as earth movement, land slide, earth skin) electrical efforts, pipelines becomes susceptible to vandalism, wear and tear, sabotage and corrosion that can eventually lead to leaks, infiltrating surface water, ground water, bio-diversity, flora and fauna, destruction of forest resources, aquatic life etc or catastrophic failure (climate change, ozone layer depletion, bush fire, contamination and pollution of water, air, land etc). the use of Unmanned Aerial Vehicle to monitor and capture real-time imagery along the Pipeline Right of Way (PROW) is thus creative and innovative with precision and accuracy. Some UAV used for surveying, surveillance safety etc have had negative torn causing injury to man, bird and other flying aircraft which necessitated the development of new UAV with the capacity to mitigate any impeding disaster. UAV deployment in the environment with supervisory control/command and data-acquisition (SCCADA) system has made it possible to capture and monitor in real-life time the flow rate, temperature and pressure of condensate, crude, or other chemicals as it moved from the exploration unit to the flow station facility and to the final unit (depots). Pipeline leaks causes loss of natural surroundings for many animals. Pipelines affect anthropogenic activities as some areas are marked as restricted zinc, certain distances are maintained far off the PROW. Product leaks from pipelines has rendered many arable lands useless, fumes from leaks evaporate into the cloud and forms rain cloud, when precipitated it drops as acid rain. Pipeline disaster the likes of pipeline explosion, fires and pipeline product emissions are the fundamental drivers of unnatural weather change over a period of time. Some much of carbondioxide CO_2, methane, ethene etc gases effect on the greenhouse gases GHG in air changing the water cycle, it also disintegrates soil, and diminishing biodiversity. Sections of pipeline route add to deforestation whenever trees and plant are expelled resulting to carbondioxide emanating oxygen into the air, which has depleted forest reserve with about 12%. It is assessed that up to 80% of the world's realized biodiversity lives in the rainforest, and the demolition of those rainforest is quickening annihilation of a disturbing rate. The broad environmental degradation faced by the local and international oil and gas exploration and production sector are manifested at both local and international levels. Amongst them are; habitat protection and biodiversity, gas emissions, fumes, marine and fresh water discharges, oil spills, and soil and ground water contamination and pollution. The major effects to soil arise from three basic sources such as: (1) A result of construction activities, the physical disturbances are perceived (2) Contamination as a result of spillage and leakage or solid waste disposal system and (3) Indirect effect cause by social change from opening access.

Potential effects may occur as occasioned to various components of the biosphere from a variety of operational sources (e.g. terrestrial, aqua, atmospheric) plants and animals' lives are affected by direct changes in their environment via variations in air water and soil quality and disturbance by noise and changes in vegetation cover. Such changes have direct effect on ecology such as, habitat, food and nutrient supplies, areas for breeding, herbivore grazing pattern, migration route, erosion, etc.

Pipeline right of way (PROW) has a potential that threatens people, the environment and property as a result of anthropogenic activities not limited to farm land. However, even with good conceptual planning, execution, implementation of correct procedures and individual awareness through training incidents do occur such as, spillage of fuel-crude, kerosene, gas, oil, chemicals and hazardous materials explosions, fires, oil and gas well blowouts, sabotage, war un-plan plant upset and shutdown, natural disaster – earth movement, flood, earthquake and its implications on operations.

7.0 Pipeline Network Monitoring and Management Aided with UAV

The typical pipeline network is shown in fig 2. The dimensions of the pipes used is shown to increase from the well location (well location for crude or gas, borehole well for water) it doesn't matter if the pipeline is carrying water or crude oil or gas, to ensure integrity of the structural pipeline and pipeline security, large commercial, civil and industrial proponents / companies use quality and enhanced safety gadgets and superlative maintenance culture. This is to make certain that the pipeline is mechanically viable, sound and eventually free from third party interference – not limited to pressure detection, leakage, developing corrosion, low or high temperatures and others.

The pipeline from the well location through the flow-lines to the flow station. The output of the flow station is fed either to a large / small manifold using a delivery line/pipe to the main manifold using pipeline. Another lien is tag as the trunk line that is use in supplying pipeline product / crude oil through the pipe to the export terminal or the refinery. In the diagram below it is assessed that the major pipeline known as the trunk pipe if effected negatively upon could halt and shut down the delivery of crude / water to the needed spot. This trunk line is the costliest and critical pipe in the network. With the aid of UAV, the programme pipeline network can be assessed through the PROW, data pattern: digital elevation model, 3-dimentional, 2-dimensional view fed back to the GIS at the base station to analyse the geo-data, imagery and video clips taken during the vehicle. In Fig 1 the drawings show the architectural diagram, the pipeline network is being illustrate starting from the layout of the wells with pipeline leading to the small manifold which is later fed to the processing facilities and export terminals – through the large manifold comprising of booster pumps. The UAVs are distributed at equidistance to each manned ground or floating station closet to the intersection cells along the PROW. The UAV is used to provide long-short distance cover for the cells with the same colours. The pipelines are arranged in a cell so that the UAV can fly / hover within the programmed sensor cell. The sensors are also implanted along the pipeline path or is attached to the structure of the pipeline at distances – This will ensure that suspected attacks or multiple true alerts are detected, inspected, monitored simultaneously.

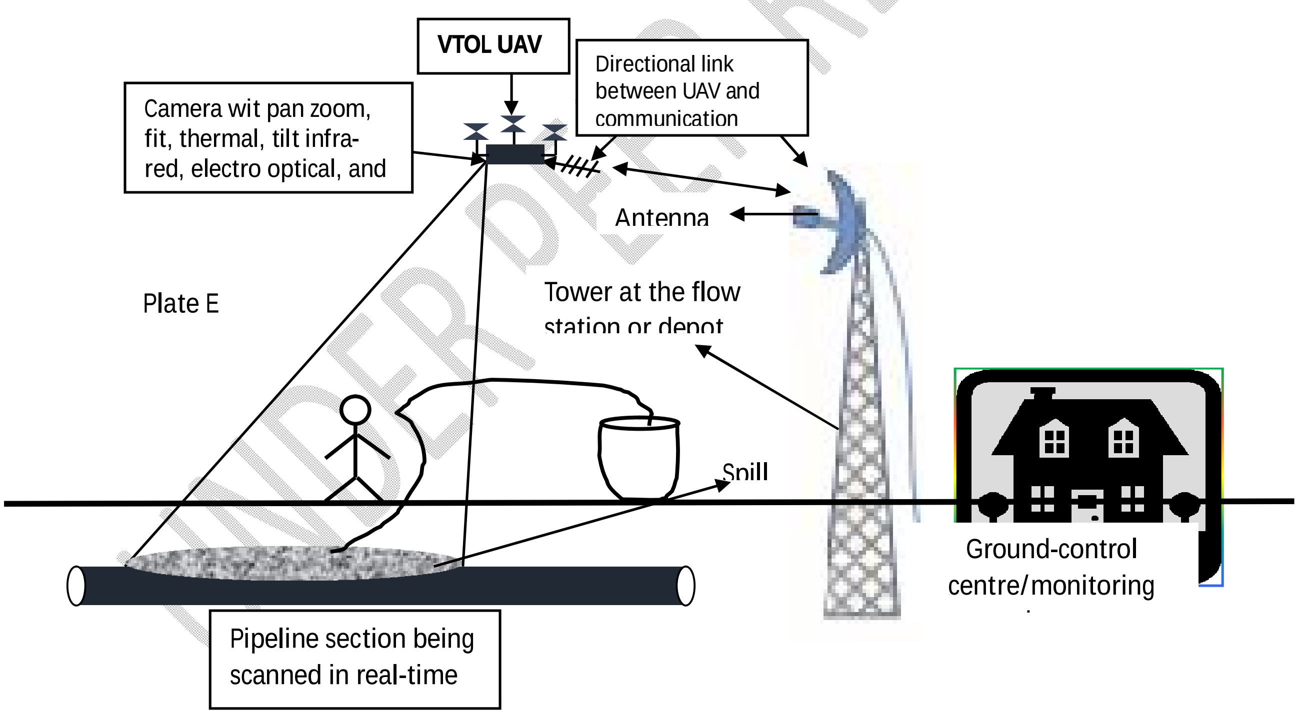

Figure 1: Architectural diagram of Portable easily deployable VTOL

8.0 UAVs Security and the Risk of Cyber Crime

Cyber-security risks are no longer just limited to computer wares and smartphones. The case of cyber-criminals, UAVs, MAVs and other flying vehicles in the sky is not limited to attacks from programmers-hackers, internet thieves; sabotage set their sights on UAV-drones. Unmanned Aerial Vehicles are becoming very popular with remarkable exploit as there is no shortage of people wanting to fly their equipment carrying cameras and distinct sensors to get a perfect shot, spy on people's privacy. UAV can pose a security threat as researchers claimed that Drones may not carry only cameras but can be used to carry weapons, explosives, bombs and toxic chemicals-making drone an ideal weapon for criminals, espionage, terrorism and smuggling. In ICAO [35] states: "countering drones is now a global issue and an increasing concern for the military, the government and the homeland security force across every continent". New rules by FAA (Federal Aviation Authority-US) says that anyone above 16years can fly a drone hence, it is expected that over 600,000 drones will be used for commercial purpose within the coming year. UAVs – Drones can be used by organizations for deliveries [21] protection of border-security, the military for spying operations, taking real-time-imagery and for stealing relevant information as some drone can detect username and access someone smartphone [36]. Drone defence system can be equipped to disrupt intruder drones. This is one of the security measures deployed for full implementation on the use of drone. The method used fig 2 neutralizes intruder drones which will lead to drone crash causing harm to individual or to property. Drones used by intruders to steal classified data, smugglers, terrorists, and other criminal activities must be neutralize to keep the airspace free.

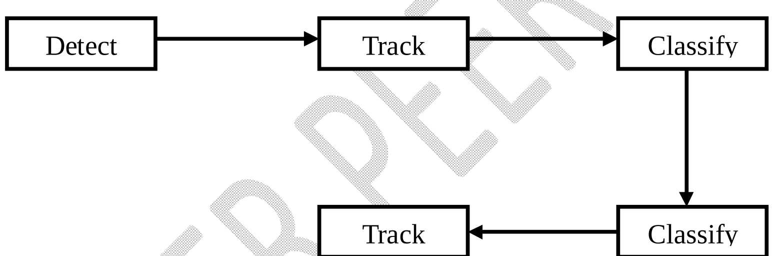

Figure 2: A five model for UAV security

As emerging anti-drones (UAVs) technologies continue to develop, agencies, government, organization be it commercial, and consumer information will be protected from cyber-criminals. Until that happen the researchers opined and recommend the above model to defend drone (UAV) against ugly drone UAV incursions.

Conclusion

The use UAVs enables digital surveillance of pipelines along pipeline right of way, to observe trends anddetect as well as monitor changes along pipeline networks. The advantages of this technology are not limited to obvious benefit of asset safety but also to the prevention of environmental pollution, which is often very common in communities through which the pipelines pass.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Details of the AI usage are given below:

1.

2.

3.

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